PERFORMANCE ANALYSIS OF MACHINE LEARNING BASED OPTIMIZED SCHEDULER FOR RESOURCE ALLOCATION IN IIOT ENVIRONMENT

A SYNOPSIS

Submitted by

SENTHILKUMAR P
(Reg. No. 201711221)

in partial fulfillment for the award of the degree
of

DOCTOR OF PHILOSOPHY

DEPARTMENT OF INSTRUMENTATION AND CONTROL ENGINEERING
SCHOOL OF ELECTRONICS, ELECTRICAL AND BIOMEDICAL TECHNOLOGY
KALASALINGAM ACADEMY OF RESEARCH AND EDUCATION
(DEEMED TO BE UNIVERSITY)
ANAND NAGAR, KRISHNANKOIL – 626 126
TAMIL NADU, INDIA

JULY 2023

1. INTRODUCTION

In recent times, the Internet of Things (IoT) is integrated with the cloud's intrinsic proficiencies to transform the field of industrial automation. IoT devices complement cloud proficiencies with developing computing and network connectivity [1]. Smart manufacturing in the automation industry involves the integration of the cloud with other supplementary devices. This collaboration helps to enhance automation in different industries by enabling smart manufacturing [2]. The integration of a complete spectrum of industries and enterprises is important to enhance the pattern and development. For the effective functioning of IMS, collaborative manufacturing patterns or designs like object management devices, and cloud-based resources must be used to manage a huge variety of manufacturing elements [3]. Presently, the incorporation of IoT services with the cloud demands appropriate transformation. However, it lacks engineering models to achieve transformation in industries [4]. Moreover, it faces a challenge in reliability, security, and performance [5]. Thus, the integration of cloud [6]and IoT [7] in industries must concentrate on these factors to improve their performance.Hence, an effective methodology is required to utilize the IoT services in tandem to perform the desired task. The framework must effectively transform the traditional automation framework in industries. Presently, various Artificial Intelligent techniques like Machine Learning (ML) and Deep Learning (DL) based approaches are utilized for the adoption of industrial automation. The DL model includes, Deep Neural Network (DNN) is widely used for automation in industries, which consists of IoT and cloud systems. Furthermore, various engineering-based models are designed to achieve optimization of the task in a cloud environment. In this research, the Deep Learning-based Model Based Engineering (DL-MBE)is proposed to execute the industrial workflow in the cloud-based Industrial Internet of Things (IIoT).

1.1 Problem Statement

The cloud-assisted IIoT integrates the cloud function and IoT networks in industrial applications, which enables the enhancement of the manufacturing and production process. Moreover, it supports to design of the product which can alter/change itself following industrial demands. However, the IIoT network faces significant challenges in providing the service at a low cost. The high energy consumption, latency, task response time, etc., are some of the other issues in the cloud-based IIoT system. In addition, optimizing the industrial workflow is another difficulty

in cloud-IIoT. Although various approaches are developed to predict the cloud workflow, they suffer from high energy and time consumption.

1.2 Research Objectives

The main contribution of the presented research is described below,

- To develop and model a hybrid Model-Based Engineering (DL-MBE) to predict and optimize the industrial workflow in cloud-IIoT.
- To create an intelligent approach using the Deep Learning algorithm to track the reference signal voltage optimally.
- To design a Deep Neural Network (DNN)-based MBE framework to resolve the optimization problems in cloud-IIoT.
- To develop an Artificial Neural Network (ANN) with an MBE model to optimize the cloud workflow with less energy and time consumption.
- To design an integrated Deep Neural Multi-Layer Perceptron (DNMLP)-based MBE model to monitor the reference signal with reduced energy and voltage.
- To design an intelligent MBE framework using the Convolutional Neural Network (CNN) to minimize the energy consumption and pumping voltage in the testing phase.
- To develop a Recurrent Neural Network (RNN)-based MBE model with three modules to reduce the task response time irrespective of high input data acquisition rate.

2. LITERATURE SURVEY

The evolution of IIoT devices potentially increases the security threats like data hacking, denial of service, etc. Zolanvari *et al.* [8] suggested that big data analytics and machine learning approaches are emerging techniques in securing IIoT devices. In this framework, certain IIoT protocols are utilized to encounter security threats. Further, a cyber-security analysis was performed to deliberate the usage of ML in predicting cyber-attacks. Moreover, a literature survey was presented to analyze the IDS using ML design. In addition, a case study was carried out to illustrate the effectiveness of the proposed ML-based IDS in IIoT applications.

Although the IIoT network increases the performance of the industrial sector, it faces a significant challenge in security and privacy. Thus, Shahid Latif *et al.* [9] presented an integrated

cyber-security framework to detect the security threats in IIoT effectively. This hybrid system improves the security and privacy of the system and predicts security threats. The effectiveness of the proposed scheme was validated by launching several security attacks like Denial of Service (DoS), Distributed Denial of Service (DDoS), etc., in the system.

Guo *et al.* [10] proposed a federated learning algorithm to illustrate the flexible management of data in Mobile Edge Computing interconnected IIoT system. Here, all IIoT tasks are computed by utilizing the computational access point. The centralized approach-based resource allocation optimizes the performance of the IIoT system. However, this approach is not efficient and flexible. To overcome this issue, an integrated federated learning approach was proposed in this framework.

The rapid growth of Dl approaches in smart factors demands an effective cyber-physical system to enhance the flexibility and scalability of IIoT networks. Andronie *et al.* [11] developed an advanced cyber-physical system to enhance the security in real-time IIoT applications. In this research, a quantitative analysis was carried out to determine the network manufacturing system, industrial manufacturing process, smart production process, and industrial cyber security system.

In IIoT networks, the complex industrial parameters lead to the mixture of various signals from different IIoT devices. The difficult interface created by the mixture of signals causes the IIoT network inefficient in classifying the signals. The misclassification of signals consumes more time and leads to inefficient feature extraction. Moreover, the constrained channel resources make the optimization process difficult in distributed industrial sensor networks. Liu *et al.* [12] developed a signal classification approach to overcome this problem. This model includes a feature fusion technique to extract the signal features.

3. SYSTEM ARCHITECTURE

In this research, industrial workflow optimization is analyzed using different hybrid techniques. Each technique hybrids two different approaches namely, the DL algorithm and MBE framework. The optimal tracking of the reference signal enables the system to resolve the optimization problems like cost, latency, task response time, and computational time.

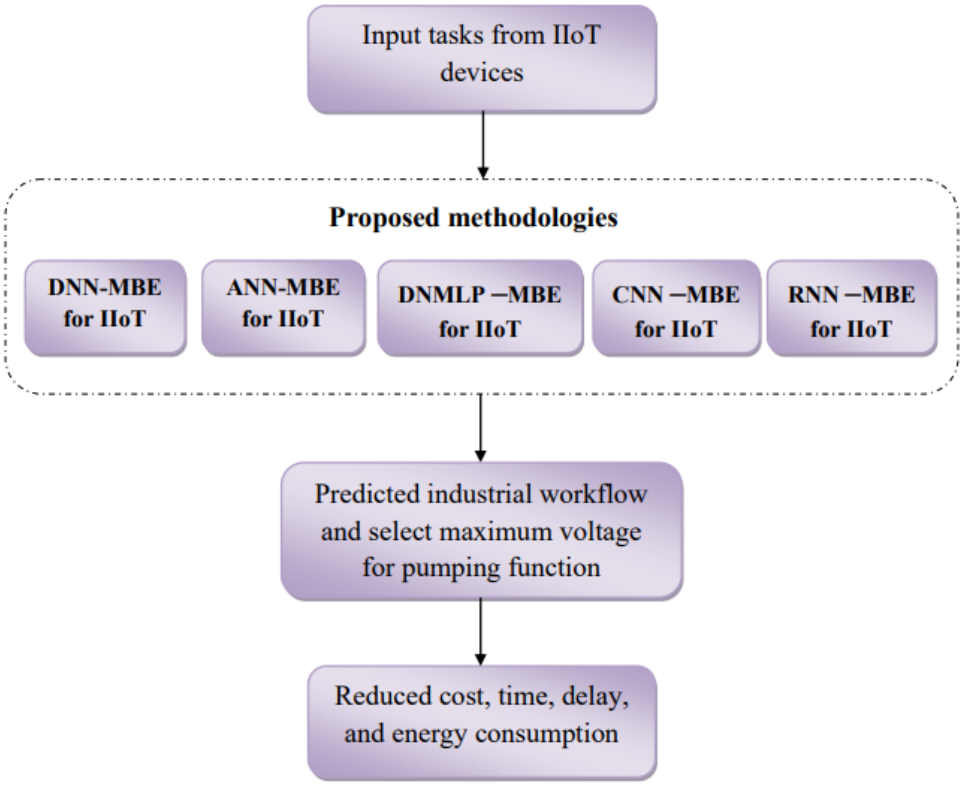

Input tasks from IIoT devices
Proposed methodologies
DNN-MBE for IIoT
ANN-MBE for IIoT
DNMLP –MBE for IIoT
CNN –MBE for IIoT
RNN –MBE for IIoT
Predicted industrial workflow and select maximum voltage for pumping function
Reduced cost, time, delay, and energy consumption

Figure.1 Research Methodology

The research work is divided into five chapters for optimizing the industrial workflow by finding the maximum voltage for the pumping function in the cloud-IIoT network. The proposed frameworks have been designed to optimize the reference signal with minimal energy consumption. Moreover, it analyzes whether the reference signal optimization and pumping function are carried out with less time and energy consumption. Figure 1 illustrates the overall research methodology.

4. PROPOSED APPROACH

4.1 DNN-MBE framework for IIoT analysis

In this section, an industrial workflow in a cloud-based IIoT framework has been developed to enhance the tracking of the reference signal. The hybrid DNN-MBE model has been designed to optimize the industrial operation by proper selection of reference signal. This design enables the pumping function to be alleged optimally with maximum voltage. Although

various models were proposed related to cloud-assisted IIoT, they face significant issues in the selection of reference voltage. The proposed method evaluates the research gap in the existing techniques and solves the task optimally by utilizing the DNN. The DNN network helps to find the maximum voltage for the pumping function. Moreover, it is observed that the existing techniques failed to offer details about task scheduling. This issue is concentrated in the proposed DNN model, which gathers the rapid acquisition of input signals from the IoT networks and assigns it concerning the availability of Virtual Machines (VMs) in the cloud network.

4.2 **ANN-MBE** *framework for IIoT analysis*

In this module, a cloud-assisted IIoT industrial workflow framework has been designed to optimize the process flow by selecting the reference signal effectively. This approach integrates the machine learning technique named Artificial Neural Network (ANN) and MBE to optimize the industrial process flow. The enhanced reference signal selection helps to maintain the pumping function at high voltage. Typically, the model-based engineering concept is applied in the cloud-IIoT system to enhance the workflow process. However, the existing techniques were not concentrated on optimal reference signal selection. Thus, the existing models failed to offer information related to task scheduling. In recent times, the ANN algorithm is deployed in IoT networks to gather information from the devices. Further, the ANN design helps to assign/schedule the task following the availability of VMs in the cloud environment. The ANN gathers the IoT device signal and allocates the tasks effectively concerning the virtual machine availability in the data plane. Moreover, it helps in selecting the reference signal voltage optimally, which increases the system performance in terms of cost, and computational time.

4.3 DNMLP-MBE framework for IIoT analysis

In this section, a cloud-based workflow framework has been developed for the industrial field (IIoT), which integrates the Deep Neural Multi-Layer Perceptron (DNMLP) with Model Based Engineering (MBE) to improve the industrial workflow by increasing the reference signal range. This helps to maintain the pumping operation optimally at high voltage. The existing work does not focus on reference voltage collection. In the developed model, the DNMLP-MBE framework tackles the task to estimate the maximum voltage for operation. This is considered

the basic difference between the traditional and presented model. Moreover, in this study, the task schedule data is considered, which helps to gather and assign the DNMLP-MBE template for the faster acquisition of IoT systems.

4.4 CNN-MBE design for IIoT analysis

In this section, an integrated CNN-MBE framework has been developed to predict the industrial workflow in cloud-IIoT system. The hybrid CNN-MBE approach enhances the workflow process by selecting the reference signal optimally. At high voltage, the presented model ensures the optimal maintenance of the pumping function. The typical MBE framework does not focus on the collection of reference signal. In addition, it cannot offer details regarding the task scheduling in cloud-IIoT. The CNN-MBE model helps to collect the input signal from different IoT devices and assigns the tasks concerning the VM availability in the cloud environment. In the presented work, the input signals are gathered from same or different IIoT devices.

4.5 RNN-MBE model for IIoT analysis

In this section, a hybrid industrial workflow model has been proposed to provide optimal scheduling in the cloud-IIoT framework. In this framework, the RNN algorithm has been integrated with the MBE approach to optimize the scheduling process. The RNN algorithm has been trained to predict future task loads and schedule the task based on the availability of the virtual machines in the cloud environment. The scheduling process is carried out depending on the input data from the IIoT systems.

5. RESULT AND DISCUSSION

5.1 Proposed DNN-MBE design

A DNN model with MBE has been designed to analyze the cloud-assisted IIoT in selecting the optimal reference signal. The variations made in the model are validated from the estimated outcomes. The verification process involves an iterative approach, and the results are determined by varying the number of tasks in the system. A simulation has been performed to validate the merits of the interconnected cloud IIoT system with MBE. Furthermore, to verify the efficiency of the developed scheme, the performance of the designed model has been compared

with the conventional benchmark approach. Moreover, it is analyzed whether the tracking and selection of the reference signal are carried out with less time and minimal voltage for pumping functions.

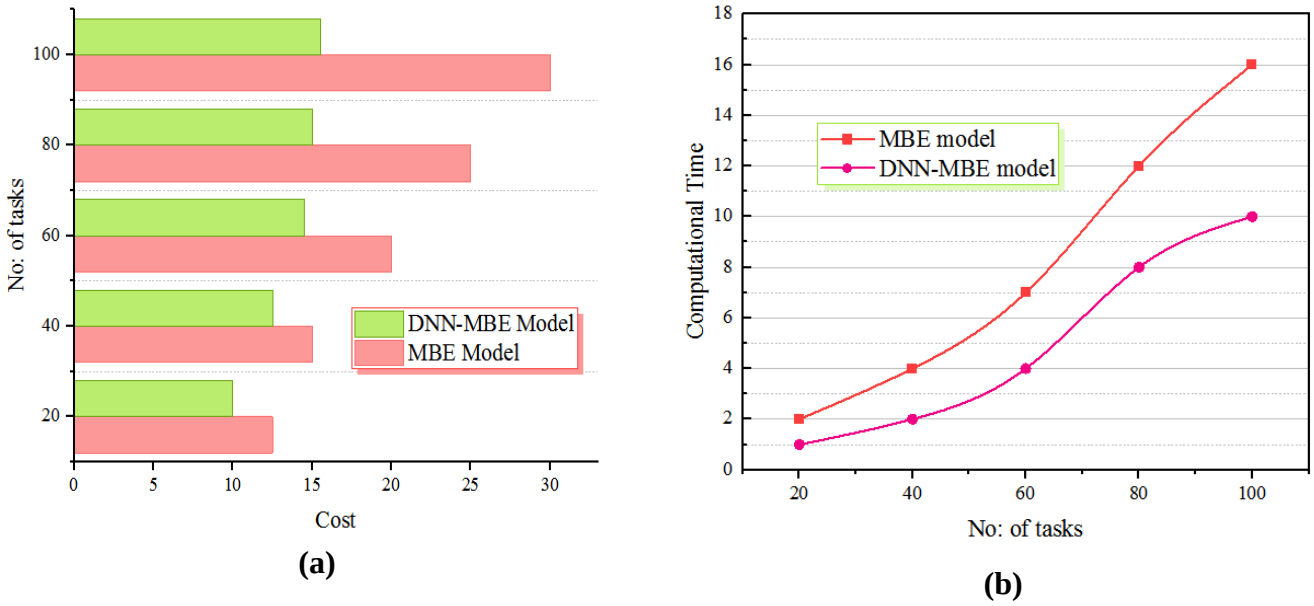


Figure.2 (a) Cost Validation, (b) Computational Time validation

In addition, the task interconnected with cloud IIoT design is analyzed based on the resources allocated in the cloud network. The Figure 2(a) shows the cost ($) for the scheduled task before and after optimizing the task scheduling using DNN, where the proposed method effectively involves the optimization of tasks between the IoT device and the cloud for the industrial automation process with a better selection of pumping voltage at the background. Figure 2(b) shows the computational time before and after optimization. This optimal selection has enabled the system to reduce its operating cost more than the existing framework.The optimal scheduling of the tasks using the DNN network helps to minimize the cost in the proposed model. Similarly, the computational time performance is evaluated in two phases to show the importance of optimization

5.2 Proposed ANN-MBE framework

In the module, a hybrid ANN-MBE framework has been designed to improve the tracking of the reference signal in a cloud-based IIoT system. The results of the proposed design have been

evaluated by performing a simulation. The simulation results illustrate the advantages of the interconnection between the cloud and IIoT devices. Further, to verify the efficiency of the ANN algorithm, the estimated results are compared with the benchmark method (MBE). In addition, an analysis has conducted to check whether the referenced signal is tracked at less time consumption and less pumping voltage.

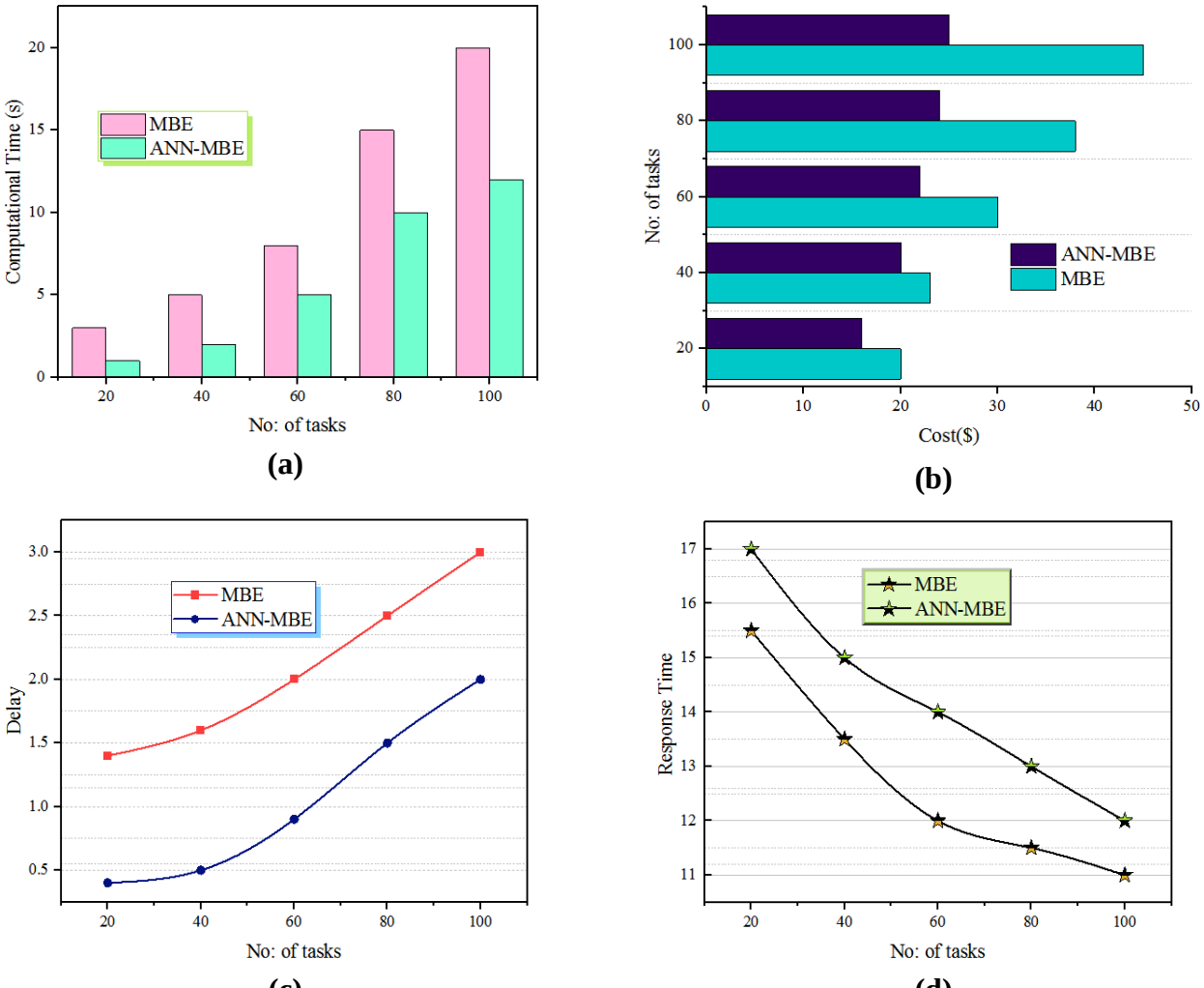


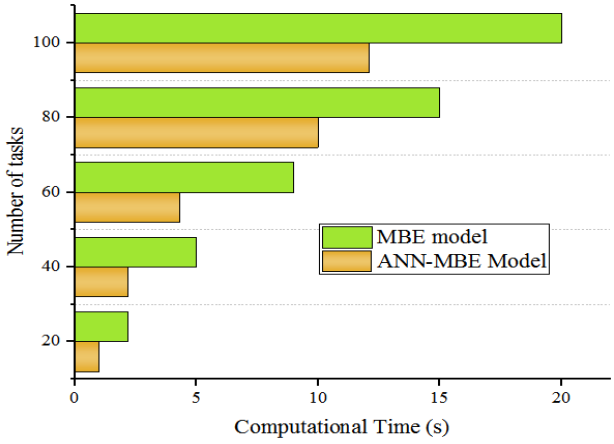
Figure.3: (a) Validation of computational time, (b) Evaluation of cost, (c) Comparison of Delay, and (d) Response time validation

Figure 3(a) shows the computational time before and after optimization. Figure 3(b) displays the evaluation of cost. Figure 3(c) illustrates the delay before and after optimization. Figure 3(d) shows the response time before and after optimization. The comparative analysis proves that the

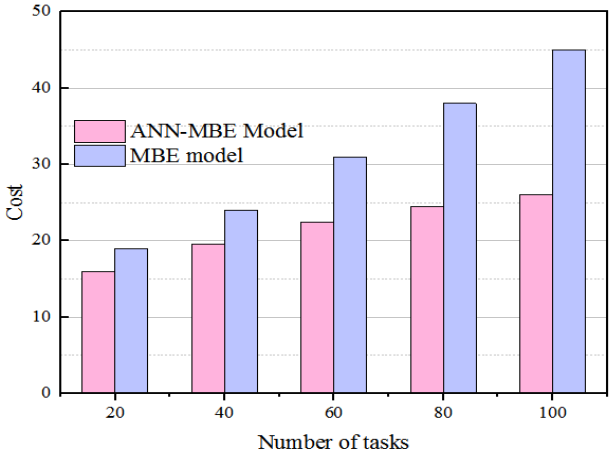
developed model is more effective in task scheduling with minimum time consumption, cost, delay and response time than the existing MBE framework.

5.3 Proposed DNMLP-MBE framework

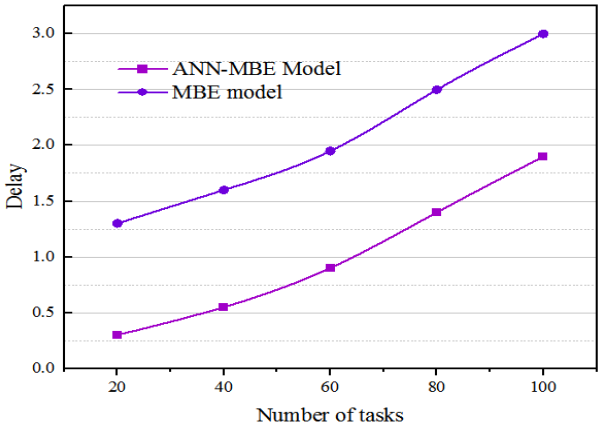
In this section, the outcomes of the proposed design has been evaluated and validated with a typical MBE framework. The simulation results illustrate the merits of cloud-IIoT with the MBE framework. In addition, it evaluates the robustness of the proposed DNMLP-MBE model by comparing it with the typical method. Moreover, it is analyzed that the reference signal is chosen for pumping action with less time and energy consumption. Furthermore, the cloud-IIoT system activities are analyzed using the optimal cloud-based reference signal handling.



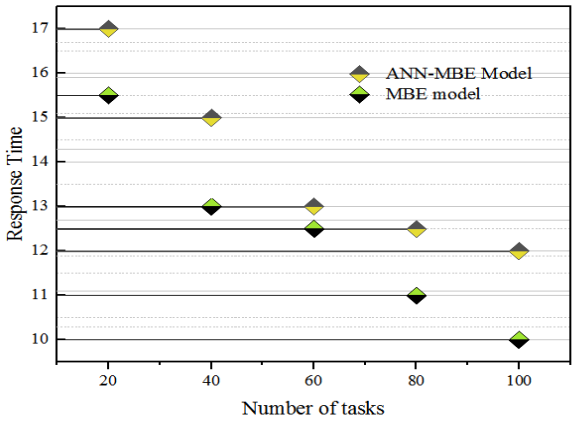
(a)



(b)



(c)



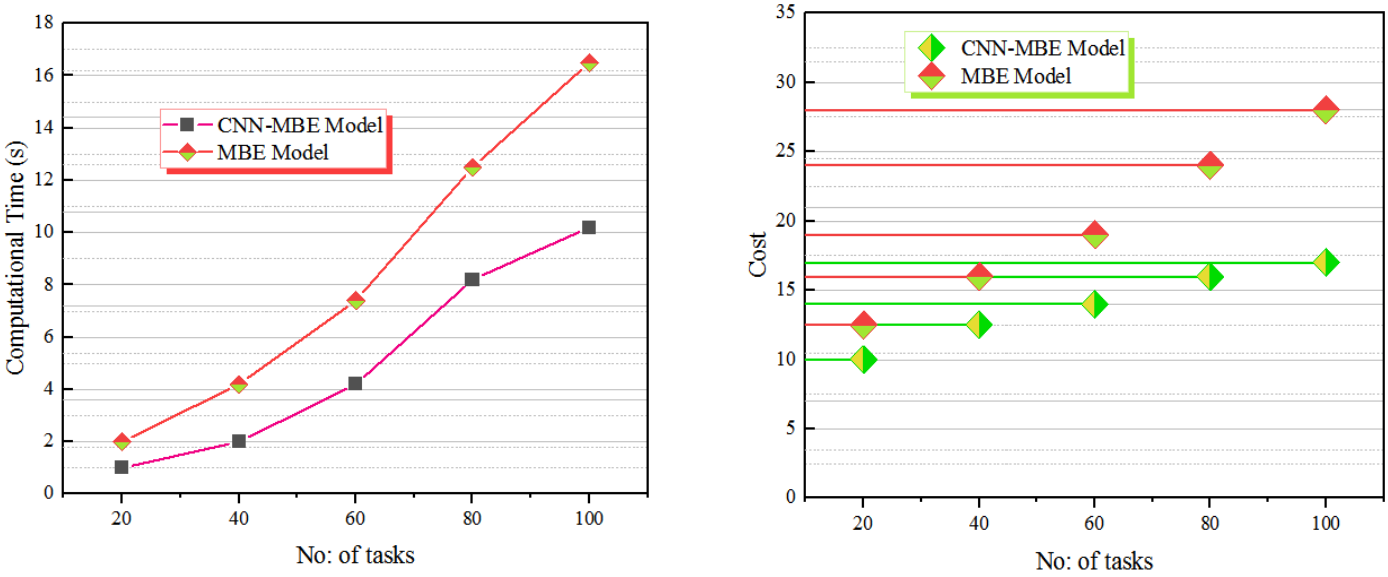
(d)

Figure.5: (a) Computational time validation, (b) Cost for scheduling task, (c) Delay befor and after optimization, (d) Response Time validation

The outcomes of the presented model are shown in Figure 5. The computational time before and after optimization is shown in Figure 5(a). The cost for the task scheduling in IIoT is illustrated in Figure 5(b). The delay for task scheduling is displayed in Figure 5(c). The response time before and after optimization is illustrated in Figure 5(d).

5.4 Proposed CNN-MBE Framework

In this section, the performances like computational time and cost are determined by conducting the simulation. Here, the simulation has been conducted with the same/different IIoT devices. Further, the simulation results are compared with the benchmark MBE framework to test the effectiveness of the proposed design.



(a) **(b)**

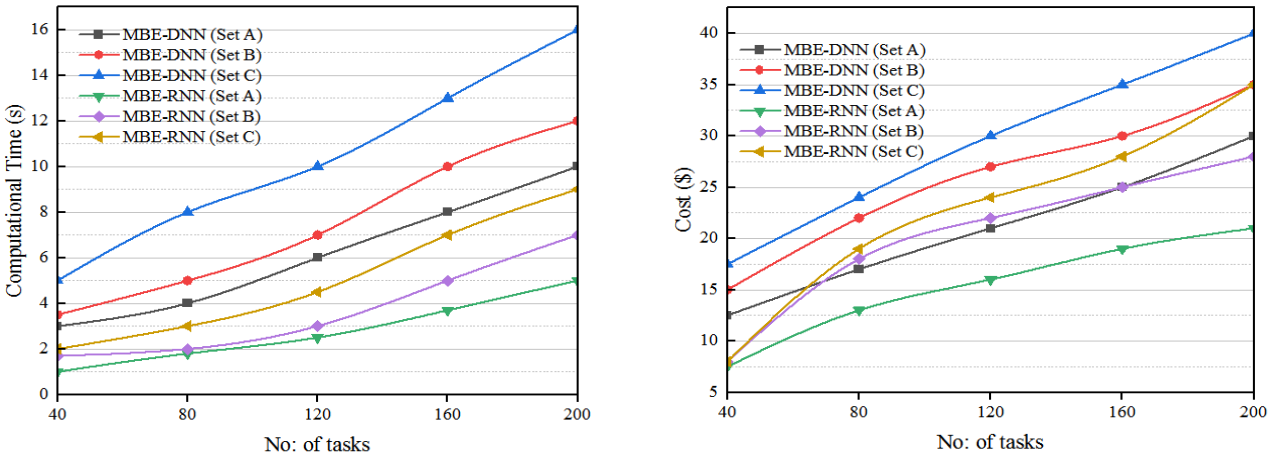
Figure.6: (a) Computational time for task scheduling in IIoT, (b) Cost efficiency before and after optimization

The results of the presented algorithm are shown in Figure 6. The computational time for task scheduling before and after the optimization of the reference signal is Figure 6(a). The cost for scheduling tasks is shown in Figure 6(b). The optimization of reference signals using CNN

minimizes the running costs compared to the traditional schemes. Moreover, the integration of CNN reported that the tasks between the cloud-IIoT and IoT system should be optimized for enhancing the pumping voltage selection.

5.5 Proposed RNN-MBE framework

In the performance analysis section, the outcomes of the proposed design have been evaluated in terms of cost, computational time, response time, and energy consumption. The validation process includes the iterative approach in which the performances are estimated by changing the number of tasks. The simulation has been performed to validate the merits incorporated with Cloud-IIoT in the MBE framework. From the estimated outcomes, the changes made in the model can be validated. Further, the results are compared with the DNN model to manifest the advantages of the proposed mode. The performance and comparative analysis are performed to validate the efficiency of the presented model

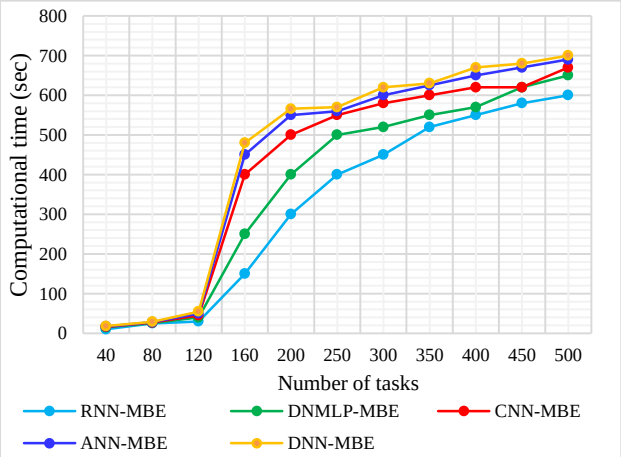


(a) **(b)**

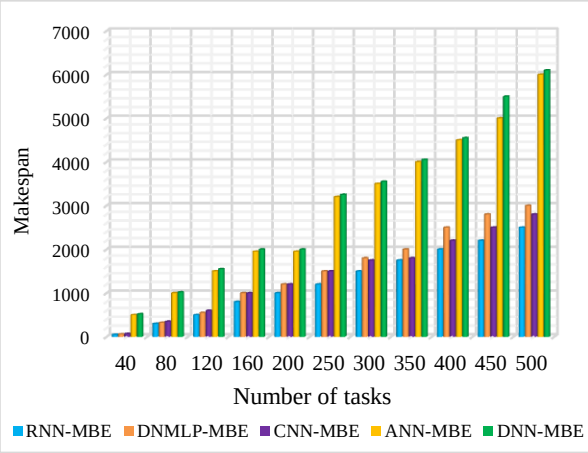
Figure.4: (a) Computational time validation, (b) Cost optimization

Figure 4 illustrates the results of the proposed RNN-MBE framework. The computational time validation is displayed in Figure 4(a). The cost optimization is shown in Figure 4(b). The comparative analysis shows that the energy consumption in scheduling the task on Set A (minimal load) has earned less energy consumption, cost, time, and response time than Set B and C. This shows that the optimal scheduling by RNN minimizes the energy consumption in the cloud-IIoT system.

Figure 5 represents the comparison of proposed RNN-MBE with previously proposed techniques such as DNMLP-MBE, CNN-MBE, ANN-MBE and DNN-MBE respectively.With regards to the computational time, a clear trend is observed in Figure. 5 (a). It was obvious that the proposed RNN-MBE algorithm, has less computation time when compared with other techniques such as DNMLP-MBE, CNN-MBE, ANN-MBE and DNN-MBE respectively.Figure 5 (b)shows the comparison of Makespan trade-off of four algorithms. It was obvious that the proposed RNN-MBE algorithm, has less Makespan when compared with other techniques such as DNMLP-MBE, CNN-MBE, ANN-MBE, and DNN-MBE respectively. When compared to other techniques such as DNMLP-MBE, CNN-MBE, ANN-MBE, and DNN-MBE the proposed method achieves makespan of 21.26%, 14.27%, 24.75% and 39.86% respectively.



(a)



(b)

Figure.5: (a) Computational time comparison, (b) Makespan comparison

6. CONCLUSION

In this research, various deep learning-based MBE frameworks were developed to optimize the industrial workflow of cloud-assisted IIoT.The proposed DNN-MBE framework tracks the reference signal with less energy consumption and optimally selects the pumping voltage. Moreover, the proposed work optimizes the industrial workflow function using repeated iteration. Finally, a simulation was performed to evaluate the results and the estimated results are compared with the benchmark MBE framework. The results are estimated for the same/different IIoT devices. Compared to the traditional MBE framework, the proposed techniques reduces the time consumption and cost by 5s, and 6$, respectively.The proposed ANN-MBE model

optimizes the industrial workflow by selecting the reference signal with less energy and voltage. This hybrid workflow optimization minimizes industrial constraints like cost, latency, response time, and computational time.

The developed scheme was validated by a simulation that follows repeated iterative processes. In addition, the presented approach evaluates whether the reference signal selection is carried out at less energy and time consumption.The presented DNMLP-MBE framework optimizes the workflow function by optimally tracking the reference signal. Moreover, it effectively minimizes the pumping voltage and energy consumption for reference signal selection. This automated optimization of workflow operation supports resolving the optimization problems like delay, cost, response time, and computational time in the cloud-based IIoT.The presented CNN-MBE algorithm provides optimal tracking of the reference signal, thus it minimizes the energy consumption in the validation phase. Moreover, it helps to select the pumping voltage optimally in the testing phase. The CNN design follows the repeated iterative approach to optimize the industrial workflow in the cloud-based IIoT. The proposed MBE-RNN model constructs three modules namely, the sensing data plane, control plane, and data plane. This triple-layered design is responsible for data acquisition, data flow prediction, and data analysis. Thus, it maintains a balance between the cloud industrial workflow and data acquisition rate. The presented approach controls the input data effectively at different rates and solves the task scheduling problem optimally.Finally, the simulation results are verified with the benchmark approach and the efficiency of the presented algorithm was estimated.

7. FUTURE SCOPE

- In the future, integrating the optimization techniques like Antlion optimization, Honeypot optimization, etc., with deep learning techniques helps to analyze the industrial workflow function irrespective of different IIoT devices and high data acquisition rates.
- The high energy consumption and pumping voltage in the testing stage of the cloud-IIoT network can be minimized by developing a multi-functional neural system.
- It is suggested to develop an algorithm that optimizes the industrial workflow in real-time cloud-assisted IIoT applications with less pumping voltage and less energy consumption.

8. ORGANIZATION OF THESIS

The organization of the thesis is presented as follows,

Chapter 2 Presents a Deep Neural Network-based Model-Based Engineering (DNN-MBE) framework to predict the workflow of industrial applications in cloud-IIoT. This chapter illustrates the demand for optimal reference signal selection. It presents the workflow of the DNN-MBE framework to minimize the misclassification errors in the system.

Chapter 3 Describes an Artificial Neural Network-based Model-Based Engineering (ANN-MBE) approach, which implements the workflow in cloud-assisted IIoT. This model optimizes the operation in the workflow by tracking the reference signal with less energy and voltage.

Chapter 4 Describes a hybrid Model Based Engineering based on Deep Neural Multi-Layer Perceptron (MBE-DNMLP) to analyze the workflow in cloud-IIoT. This model reduces energy consumption and pumping voltage by selecting the reference signal optimally. A triple-layered module was designed to perform collect and process the data. Moreover, an intelligent controller was integrated to select the reference signal optimally.

Chapter 5 Presents a Model-Based Engineering with Convolutional Neural Network (MBE-CNN) approach to optimize the industrial workflow in cloud-assisted IIoT. In this approach, the CNN architecture for cloud workflow optimization was presented. This research focuses on resource allocation and task scheduling in the cloud.

Chapter 6 Presents an integrated Recurrent Neural Network-based Model-Based Engineering (RNN-MBE) design to detect and control the workflow function in the cloud. The RNN scheduler schedules and allocates the task optimally based on the availability of the VMs in the cloud network.

REFERENCES

1. M.S. Hossain, and G.Muhammad, Cloud-assisted industrial internet of things (iiot)–enabled framework for health monitoring, *Computer Networks*, **101** (2016), 192-202.
2. S.Mumtaz, A.Alsohaily, Z.Pang, A.Rayes, K.F.Tsang, and J.Rodriguez, Massive Internet of Things for industrial applications: Addressing wireless IIoT connectivity challenges and ecosystem fragmentation, *IEEE industrial electronics magazine*, **11**(1)(2017), 28-33.
3. M.Liu, F.R.Yu, Y.Teng, V.C. Leung, and M.Song, Performance optimization for blockchain-enabled industrial Internet of Things (IIoT) systems: A deep reinforcement learning approach, *IEEE Transactions on Industrial Informatics*, **15**(6) (2019), 3559-3570.
4. T.Qiu, J.Chi, X.Zhou, Z.Ning, M.Atiquzzaman, and D.O.Wu, Edge computing in industrial internet of things: Architecture, advances and challenges, *IEEE Communications Surveys & Tutorials*, **22**(4) (2020), 2462-2488.
5. K.A.Da Costa, J.P.Papa, C.O.Lisboa, R.Munoz, and V.H.C.de Albuquerque, Internet of Things: A survey on machine learning-based intrusion detection approaches,*Computer Networks*, **151**(2019), 147-157.
6. W.Sun, S. Lei, L.Wang, Z. Liu, and Y.Zhang, Adaptive federated learning and digital twin for industrial internet of things, *IEEE Transactions on Industrial Informatics*, **17**(8) (2020), 5605-5614.
7. W.Z.Khan, M.H.Rehman, H.M.Zangoti, M.K.Afzal, N. Armi, and K.Salah, Industrial internet of things: Recent advances, enabling technologies and open challenges,*Computers electrical engineering*, **81**(2020), 106522.
8. M.Zolanvari, M.A.Teixeira, L.Gupta, K.M. Khan, and R.Jain, Machine learning-based network vulnerability analysis of industrial Internet of Things, *IEEE Internet of Things Journal*, **6**(4) (2019), 6822-6834.
9. S.Latif, Z.Zou, Z. Idrees, and J. Ahmad, A novel attack detection scheme for the industrial internet of things using a lightweight random neural network, *IEEE access*, **8** (2020), 89337-89350.
10. Y.Guo, Z.Zhao, K.He, S.Lai, J.Xia, and L.Fan, Efficient and flexible management for industrial internet of things: A federated learning approach, *Computer Networks*, **192** (2021), 108122.

11. M.Andronie, G.Lăzăroiu, M.Iatagan, C.Uță, R. Ștefănescu, and M.Cocoșatu, Artificial intelligence-based decision-making algorithms, internet of things sensing networks, and deep learning-assisted smart process management in cyber-physical production systems, *Electronics*, **10**(20)(2021), 2497.
12. M.Liu, K.Yang, N.Zhao, Y.Chen, H. Song, and F.Gong, Intelligent signal classification in industrial distributed wireless sensor networks based industrial internet of things,*IEEE Transactions on Industrial Informatics*, **17**(7) (2020), 4946-4956.

LIST OF PUBLICATIONS

1. P. Senthilkumar, K. Rajesh, Design of a model based engineering deep learning scheduler in cloud computing environment using Industrial Internet of Things (IIOT). Journal of Ambient Intelligent and Humanized Computing (2021). https://doi.org/10.1007/s12652-020-02862-7 (Impact Factor: 3.664)

2. P. Senthilkumar, Dr. K. Rajesh, Integrated Model-Based Engineering using Deep Learning with IIoT for Industry 4.0, *Journal of Information Technology Management*, **15**(s) (2023),112-123.

3. P. Senthilkumar, Dr. K. Rajesh, Analysis on Industrial Internet of Things (IIoT) Using Convolutional Neural Network Based Model Based Engineering, *IEEE- 6th International Conference on Communication and Electronics Systems (ICCES)*, IEEE Xplore Part Number: CFP21AWO-ART; ISBN: 978-0-7381-1405-7

4. P. Senthilkumar, Dr. K. Rajesh, Analysis on Industrial Internet of Things (IIOT) Using Cloud and Optimized Deep Neural Network Model Based Engineering, *TEST Engineering and Management*, May - June 2020 ISSN: 0193-4120 Page No. 18531 – 18535

5. P. Senthilkumar, Dr. K. Rajesh, Analysis on Industrial Internet of Things Using Cloud and Optimized Artificial Neural Networks Model Based Engineering, *International Journal of Advanced Science and Technology*, **29** (06), (2020), 6932-6938.

6. P. Senthilkumar, Dr. K. Rajesh, Analysis on Industrial Internet of Things Using Deep Neural Multi-Layer Perceptron Based Model-Based Engineering, *Turkish Journal of Computer and Mathematics Education*, **12** (10) (2021), 5550-5555.